## SYSTEMATIC CORRECTIONS TO THE CALAMA, CHILE, SOLAR CONSTANT VALUES.

551.590.2 (83)

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, D. C., Sept. 22, 1921.]

Montezuma: Elev. = 9500 ft. (2896 meters)

As stated in the MONTHLY WEATHER REVIEW for February, 1919, when the regular publication of the solar constant values observed in Chile by the Smithsonian expedition was begun, the values published were regarded as preliminary. That is to say, the results were given just as they were received from the field, and it was not until a considerable body of the South American solar-constant values were available that a general survey of them could be taken in order to have a basis for the determination and correction of such systematic errors as might appear. The occupation of the station at Calama having ceased on July 26, 1920, with the removal of the station to Mount Montezuma, the whole body of the Calama results can now be examined from a general point of view for the purposes just mentioned.

First of all, it was desirable to determine whether the solar-constant values were in correlation with the prevailing atmospheric humidity. Such a correlation, as readers of Volume III of the *Annals of the Astrophysical Observatory* will find described at page 43, was discovered in the Mount Wilson observations by grouping the solar-constant values between certain limits of precipitable water prevailing in the atmosphere, as determined by Fowle's method. In discussing the Calama results, the logarithm of the ratio $\rho/\rho_{sc}$—that is to say, the logarithm of the depression of the curve at the water vapor band $\rho$—was used as the function of atmospheric humidity. The values of the solar constant were grouped with respect to this variable, with the following results:

*Influence of atmospheric humidity on Calama solar-constant values.*

[Observations of July 27, 1918, to June 30, 1919. Long method only (bolographic).]

| Number of observations | 22 | 20 | 32 | 35 | 37 | 34 | 38 | 26 |
|---|---|---|---|---|---|---|---|---|
| Mean log $\rho/\rho_{sc}$ | $\bar{1}.510$ | $\bar{1}.573$ | $\bar{1}.631$ | $\bar{1}.673$ | $\bar{1}.726$ | $\bar{1}.771$ | $\bar{1}.828$ | $\bar{1}.867$ |
| Mean solar constant | 1.9302 | 1.9147 | 1.9126 | 1.9485 | 1.9362 | 1.9373 | 1.9516 | 1.9550 |

[Observations of July 1, 1919, to July 26, 1920. Long method only (bolographic).]

| Number of observations | 17 | 19 | 20 | 14 |
|---|---|---|---|---|
| Mean log $\rho/\rho_{sc}$ | $\bar{1}.497$ | $\bar{1}.663$ | $\bar{1}.749$ | $\bar{1}.830$ |
| Mean solar constant | 1.9506 | 1.9504 | 1.9171 | 1.9525 |

The range of water vapor prevailing at Calama is nearly, but not quite, as great as that which has prevailed at Mount Wilson, but the march of the mean solar-constant values with respect to the logarithm of $\rho/\rho_{sc}$ does not appear to indicate with any certainty that there is any correlation between these quantities. We have not felt justified, therefore, in introducing any secondary correction for the prevailing humidity at Calama similar to the secondary correction which is applied for this purpose to the Mount Wilson results. Accordingly, the values of the solar constant determined by the fundamental or long method at Calama will stand as heretofore published, so far as we can now predict.

Turning now to the values determined by the empirical or short method, whose dependence on the long fundamental method has been described in this REVIEW for August, 1919, the accuracy of the short method results evidently depends upon the accuracy of the curves which have been drawn connecting the values of the function $\rho/\rho_{sc}$ with the atmospheric transmission coefficients determined by many long method observations. The different parts of this curve were determined with very different degrees of certainty. For those regions where the value of the function was small and which corresponded to clear dry days, there were so many observations by the long method available as their basis that these parts of the curve are not likely to be seriously in error.

Not so for the regions of the curve corresponding to very large values of the function—that is, to skies of great haziness associated with high atmospheric humidity. At such times solar-constant values by the long method are seldom obtained, and when obtained are liable to be in error, due to change in the transparency of the atmosphere during the several hours required for the long-method determinations. It seems, therefore, particularly desirable to determine whether the short-method results appear to be systematically in error for different values of the function.

It will be recalled that the short-method solar-constant values are computed by the aid of three sets of curves—one set corresponding to observations at air mass 3, another at air mass 2, and the third at air mass 1.5. In the study of the matter we therefore gathered all of the solar constant values, first, into the three divisions corresponding with the three sets of curves from which these divisions were severally determined. Secondly, in each of these grand divisions we divided the solar constant values into groups between different limits of the function values. While the high and low function values are prevailingly associated with special seasons of the year, yet a very fair distribution of them occurs over the entire annual period. Accordingly, when a large group of, say, 20 to 50 solar-constant values is selected, corresponding to functions values between certain narrow limits, this group of solar-constant values covers a great variety of days fairly representative of the whole year. The mean of such a group will be very little subject to fluctuation owing to the real variability of the sun. Hence, we made the assumption that the mean values of the groups within the 13 months, July, 1919, to July, 1920, inclusive, should be identical, and should be identical with the mean value of the solar-constant values scattered through this interval of time which were determined by the long method.

The latter value was found to be 1.951 calories per square centimeter per minute. Accordingly, the deviations of the mean values for the various groups from the standard values, 1.951, were regarded as an indication of the amount of error due to the employment of defective function-transmission curves within the various limits of the several groups.

This system of deviations having been plotted with respect to the values of the functions corresponding, a correcting curve was thereby obtained for short-method observations taken at Calama by each of the three sets of curves corresponding respectively to air masses 3, 2, and 1.5. In the following table are given, in illustration, the results of the discussion for air mass 2.

*Dependence of solar constant on function values.*

[Calama observations July 1, 1919, to July 26, 1920. Short method only (pyranometer). From curves for air mass 2.0.]

| Number of observations. | 66 | 95 | 41 | 27 | 20 | 14 | 24 |
|---|---|---|---|---|---|---|---|
| Mean value of function | 174 | 243 | 340 | 450 | 586 | 780 | 1,151 |
| Mean solar constant | 1.9451 | 1.9432 | 1.9452 | 1.9566 | 1.9630 | 1.9791 | 1.9832 |

In drawing the curve for correcting the solar-constant values, it was thought best to err on the side of minimizing rather than of emphasizing the correction where the divergence of the observed corrections from the smooth curve would tend to raise a doubt as to the best course to pursue. Accordingly, the corrections which have been applied are thought to be, if anything, slightly less in magnitude than perhaps would be advisable. However, the magnitudes of the corrections are in all cases small, and the defect in the corrections, if any, is certainly in a high degree negligible.

On this basis we have corrected each individual value for the solar constant obtained by the short method from July 1, 1919, to July 26, 1920. Data were lacking to apply the corrections for the very few days of June, 1919, when the short method was employed. However, the corrections at that season of the year were generally very small, so that this is of little consequence.

In the following table we give the original and corrected weighted mean values of the solar constant for the period in question, extending from July 1, 1919, to July 26, 1920. All other values of the solar constant observed at the station at Calama are to be regarded, at least for the present, as standing unchanged.

With regard to the solar-constant values which have been obtained at the station at Montezuma, hitherto we have not been able to assure ourselves that any correction is to be applied to them, either for the long-method or the short-method results. We prefer to wait for some time further before deciding whether or not any systematic corrections to these values must be applied.

| Date. | Weighted mean solar constant values. Original. | Corrected. |
|---|---|---|
| 1919. | | |
| July 1 | 1.935 | 1.942 |
| 2 | 1.918 | 1.925 |
| 3 | 1.922 | 1.928 |
| 4 | 1.968 | 1.980 |
| 6 | 1.964 | 1.971 |
| 9 | 1.947 | 1.954 |
| 10 | 1.951 | 1.958 |
| 11 | 1.946 | 1.954 |
| 12 | 1.949 | 1.951 |
| 13 | 1.934 | 1.941 |
| 14 | 1.953 | 1.965 |
| 15 | 1.952 | 1.960 |
| 17 | 1.955 | 1.959 |
| 18 | 1.966 | 1.972 |
| 19 | 1.979 | 1.987 |
| 20 | 1.952 | 1.961 |
| 21 | 1.953 | 1.957 |
| 22 | 1.960 | 1.971 |
| 23 | 1.959 | 1.967 |
| 24 | 1.951 | 1.955 |
| 25 | 1.960 | 1.967 |
| 26 | 1.918 | 1.922 |
| 27 | 1.916 | 1.925 |
| 28 | 1.955 | 1.959 |
| 29 | 1.951 | 1.958 |
| 30 | 1.928 | 1.936 |
| 31 | 1.915 | 1.930 |
| Aug. 1 | 1.953 | 1.959 |
| 2 | 1.935 | 1.943 |
| 3 | 1.971 | 1.980 |
| 4 | 1.954 | 1.959 |
| 5 | 1.953 | 1.963 |
| 6 | 1.936 | 1.943 |
| 7 | 1.954 | 1.962 |
| 8 | 1.953 | 1.961 |
| 9 | 1.970 | 1.980 |

| Date | Weighted mean solar constant values. Original. | Corrected. |
|---|---|---|
| 1919. | | |
| Aug. 10 | 1.958 | 1.960 |
| 11 | 1.932 | 1.939 |
| 13 | 1.920 | 1.924 |
| 14 | 1.948 | 1.946 |
| 15 | 1.953 | 1.950 |
| 16 | 1.929 | 1.932 |
| 17 | 1.947 | 1.955 |
| 18 | 1.951 | 1.962 |
| 19 | 1.918 | 1.927 |
| 20 | 1.935 | 1.943 |
| 21 | 1.930 | 1.934 |
| 22 | 1.960 | 1.966 |
| 23 | 1.953 | 1.961 |
| 24 | 1.958 | 1.964 |
| 25 | 1.954 | 1.962 |
| 26 | 1.938 | 1.945 |
| 27 | 1.945 | 1.954 |
| 28 | 1.949 | 1.957 |
| 29 | 1.961 | 1.996 |
| 30 | 1.943 | 1.451 |
| 31 | 1.934 | 1.925 |
| Sept. 1 | 1.930 | 1.937 |
| 2 | 1.912 | 1.918 |
| 3 | 1.926 | 1.934 |
| 4 | 1.941 | 1.946 |
| 5 | 1.929 | 1.938 |
| 6 | 1.937 | 1.946 |
| 7 | 1.933 | 1.941 |
| 8 | 1.943 | 1.956 |
| 9 | 1.931 | 1.937 |
| 10 | 1.921 | 1.930 |
| 11 | 1.941 | 1.948 |
| 12 | 1.915 | 1.917 |
| 13 | 1.948 | 1.956 |
| 14 | 1.922 | 1.930 |
| 15 | 1.926 | 1.933 |

| Date. | Weighted mean solar constant values. Original. | Corrected. |
|---|---|---|
| 1919. | | |
| Sept. 17 | 1.933 | 1.932 |
| 18 | 1.939 | 1.948 |
| 19 | 1.949 | 1.957 |
| 20 | 1.948 | 1.957 |
| 21 | 1.950 | 1.957 |
| 22 | 1.918 | 1.925 |
| 23 | 1.938 | 1.941 |
| 25 | 1.920 | 1.928 |
| 26 | 1.951 | 1.957 |
| 27 | 1.919 | 1.928 |
| 28 | 1.930 | 1.938 |
| 29 | 1.934 | 1.935 |
| 30 | 1.918 | 1.926 |
| Oct. 2 | 1.944 | 1.944 |
| 7 | 1.891 | 1.898 |
| 8 | 1.963 | 1.971 |
| 9 | 1.948 | 1.957 |
| 10 | 1.961 | 1.961 |
| 11 | 1.952 | 1.948 |
| 12 | 1.949 | 1.918 |
| 13 | 1.946 | 1.945 |
| 14 | 1.940 | 1.952 |
| 15 | 1.959 | 1.968 |
| 17 | 1.934 | 1.939 |
| 19 | 1.955 | 1.960 |
| 20 | 1.953 | 1.962 |
| 21 | 1.965 | 1.972 |
| 23 | 1.946 | 1.946 |
| 24 | 1.962 | 1.959 |
| 25 | 1.964 | 1.968 |
| 26 | 1.971 | 1.964 |
| 28 | 1.957 | 1.964 |
| 31 | 1.958 | 1.954 |
| Nov. 1 | 1.957 | 1.964 |
| 2 | 1.957 | 1.958 |
| 3 | 1.957 | 1.958 |
| 4 | 1.950 | 1.961 |
| 5 | 1.969 | 1.973 |
| 6 | 1.952 | 1.949 |
| 7 | 1.944 | 1.953 |
| 9 | 1.918 | 1.949 |
| 10 | 1.960 | 1.960 |
| 11 | 1.966 | 1.960 |
| 12 | 1.961 | 1.957 |
| 13 | 1.960 | 1.953 |
| 15 | 1.947 | 1.941 |
| 17 | 1.925 | 1.929 |
| 18 | 1.961 | 1.968 |
| 21 | 1.954 | 1.952 |
| 22 | 1.940 | 1.940 |
| 23 | 1.951 | 1.945 |
| 24 | 1.952 | 1.942 |
| 25 | 1.944 | 1.943 |
| 26 | 1.968 | 1.968 |
| 27 | 1.936 | 1.928 |
| 28 | 1.957 | 1.956 |
| 29 | 1.952 | 1.952 |
| 30 | 1.956 | 1.958 |
| Dec. 1 | 1.957 | 1.958 |
| 3 | 1.958 | 1.951 |
| 5 | 1.950 | 1.952 |
| 6 | 1.943 | 1.925 |
| 7 | 1.934 | 1.927 |
| 8 | 1.944 | 1.928 |
| 9 | 1.965 | 1.963 |
| 10 | 1.955 | 1.945 |
| 12 | 1.957 | 1.951 |
| 15 | 1.951 | 1.954 |
| 16 | 1.945 | 1.937 |
| 17 | 1.965 | 1.951 |
| 18 | 1.985 | 1.968 |
| 19 | 1.960 | 1.946 |
| 20 | 1.948 | 1.938 |
| 21 | 1.948 | 1.939 |
| 22 | 1.969 | 1.955 |
| 23 | 1.967 | 1.951 |
| 24 | 1.972 | 1.959 |
| 25 | 1.978 | 1.965 |
| 26 | 1.987 | 1.987 |
| 27[1] | 1.807 | 1.807 |
| 28 | 1.994 | 1.974 |
| 29 | 1.964 | 1.957 |
| 31 | 1.979 | 1.967 |
| 1920. | | |
| Jan. 2 | 1.970 | 1.969 |
| 3 | 1.976 | 1.967 |
| 4 | 1.964 | 1.960 |
| 5 | 1.964 | 1.960 |
| 7 | 1.977 | 1.949 |
| 10 | 2.027 | 2.002 |
| 11 | 1.979 | 1.975 |
| 12 | 1.955 | 1.950 |
| 14 | 1.962 | 1.956 |
| 15 | 2.000 | 1.984 |
| 17 | 1.995 | 1.987 |
| 18 | 1.981 | 1.963 |
| 19 | 1.989 | 1.978 |
| 20 | 1.947 | 1.946 |
| 21 | 1.954 | 1.929 |
| 22 | 1.973 | 1.963 |

| Date. | Weighted mean solar constant values. Original. | Corrected. |
|---|---|---|
| 1920. | | |
| Jan. 23 | 2.001 | 1.986 |
| 24 | 1.998 | 1.973 |
| 25 | 1.978 | 1.961 |
| 26 | 1.958 | 1.948 |
| 27 | 1.975 | 1.959 |
| 28 | 1.973 | 1.957 |
| 29 | 1.963 | 1.959 |
| 30 | 1.976 | 1.968 |
| 31 | 1.975 | 1.949 |
| Feb. 6 | 1.974 | 1.963 |
| 7 | 1.946 | 1.931 |
| 8 | 1.953 | 1.945 |
| 9 | 1.982 | 1.960 |
| 10 | 1.994 | 1.992 |
| 11 | 1.958 | 1.953 |
| 12 | 1.977 | 1.969 |
| 13 | 1.962 | 1.955 |
| 14 | 1.951 | 1.932 |
| 15 | 1.951 | 1.942 |
| 16 | 1.973 | 1.953 |
| 18 | 1.971 | 1.961 |
| 19 | 1.983 | 1.959 |
| 20 | 1.982 | 1.967 |
| 24 | 1.967 | 1.957 |
| 25 | 1.987 | 1.969 |
| 26 | 1.983 | 1.954 |
| 27 | 1.967 | 1.958 |
| 28 | 1.953 | 1.943 |
| Mar. 1 | 1.980 | 1.973 |
| 2 | 2.000 | 1.979 |
| 3 | 1.980 | 1.957 |
| 5 | 1.949 | 1.939 |
| 6 | 1.973 | 1.964 |
| 7 | 1.971 | 1.961 |
| 8 | 1.956 | 1.946 |
| 10 | 1.959 | 1.950 |
| 11 | 1.978 | 1.969 |
| 12 | 1.981 | 1.961 |
| 13 | 1.959 | 1.945 |
| 14 | 1.962 | 1.953 |
| 15 | 1.969 | 1.969 |
| 16 | 1.965 | 1.956 |
| 17 | 1.962 | 1.943 |
| 18 | 1.954 | 1.936 |
| 19 | 1.940 | 1.930 |
| 20 | 1.931 | 1.922 |
| 21 | 1.941 | 1.920 |
| 22 | 1.927 | 1.923 |
| 23 | 1.866 | 1.846 |
| 24 | 1.905 | 1.887 |
| 26 | 1.953 | 1.934 |
| 27 | 1.966 | 1.969 |
| 28 | 1.958 | 1.967 |
| 29 | 1.969 | 1.969 |
| 30 | 1.951 | 1.948 |
| 31 | 1.957 | 1.954 |
| Apr. 1 | 1.944 | 1.938 |
| 2 | 1.960 | 1.958 |
| 3 | 1.956 | 1.955 |
| 4 | 1.962 | 1.969 |
| 5 | 1.960 | 1.961 |
| 6 | 1.925 | 1.923 |
| 7 | 1.916 | 1.923 |
| 8 | 1.927 | 1.934 |
| 9 | 1.960 | 1.964 |
| 10 | 1.961 | 1.965 |
| 11 | 1.958 | 1.962 |
| 12 | 1.955 | 1.956 |
| 13 | 1.954 | 1.959 |
| 14 | 1.957 | 1.960 |
| 15 | 1.944 | 1.953 |
| 16 | 1.935 | 1.954 |
| 17 | 1.946 | 1.953 |
| 18 | 1.953 | 1.957 |
| 19 | 1.948 | 1.950 |
| 20 | 1.958 | 1.961 |
| 21 | 1.937 | 1.933 |
| 22 | 1.949 | 1.958 |
| 23 | 1.950 | 1.950 |
| 24 | 1.948 | 1.949 |
| 25 | 1.949 | 1.947 |
| 26 | 1.960 | 1.968 |
| 27 | 1.949 | 1.955 |
| 28 | 1.943 | 1.939 |
| 29 | 1.972 | 1.976 |
| 30 | 1.959 | 1.959 |
| May 1 | 1.933 | 1.934 |
| 2 | 1.948 | 1.957 |
| 3 | 1.961 | 1.965 |
| 4 | 1.957 | 1.962 |
| 5 | 1.938 | 1.945 |
| 6 | 1.949 | 1.951 |
| 7 | 1.952 | 1.955 |
| 8 | 1.957 | 1.965 |
| 9 | 1.921 | 1.923 |
| 10 | 1.938 | 1.941 |
| 11 | 1.968 | 1.971 |
| 12 | 1.952 | 1.962 |
| 13 | 1.955 | 1.963 |
| 14 | 1.937 | 1.952 |

[1] This long-method value is known to be worthless because of evident progressive deterioration of the atmospheric transparency.

| Date. | Weighted mean solar constant values. | | Date. | Weighted mean solar constant values. | |
|---|---|---|---|---|---|
| | Original. | Corrected. | | Original. | Corrected. |
| 1920. | | | 1920. | | |
| May 16 | 1.957 | 1.963 | June 18 | 1.933 | 1.941 |
| 17 | 1.945 | 1.952 | 19 | 1.941 | 1.942 |
| 19 | 1.959 | 1.959 | 23 | 1.939 | 1.947 |
| 20 | 1.961 | 1.964 | 24 | 1.941 | 1.942 |
| 21 | 1.930 | 1.936 | 25 | 1.914 | 1.921 |
| 22 | 1.934 | 1.939 | 26 | 1.948 | 1.951 |
| 23 | 1.939 | 1.942 | 27 | 1.918 | 1.925 |
| 24 | 1.938 | 1.942 | 30 | 1.940 | 1.939 |
| 25 | 1.963 | 1.970 | July 1 | 1.936 | 1.944 |
| 26 | 1.914 | 1.921 | 2 | 1.944 | 1.949 |
| 27 | 1.959 | 1.964 | 3 | 1.929 | 1.935 |
| 28 | 1.948 | 1.952 | 4 | 1.942 | 1.948 |
| 29 | 1.940 | 1.942 | 5 | 1.950 | 1.955 |
| 30 | 1.977 | 1.986 | 6 | 1.949 | 1.948 |
| 31 | 1.946 | 1.952 | 7 | 1.942 | 1.948 |
| June 1 | 1.933 | 1.937 | 8 | 1.945 | 1.951 |
| 2 | 1.938 | 1.942 | 9 | 1.941 | 1.944 |
| 3 | 1.956 | 1.968 | 10 | 1.927 | 1.932 |
| 4 | 1.926 | 1.929 | 11 | 1.938 | 1.945 |
| 5 | 1.955 | 1.960 | 12 | 1.938 | 1.944 |
| 6 | 1.945 | 1.951 | 15 | 1.925 | 1.933 |
| 7 | 1.933 | 1.938 | 18 | 1.921 | 1.933 |
| 8 | 1.924 | 1.929 | 19 | 1.920 | 1.932 |
| 9 | 1.936 | 1.940 | 20 | 1.942 | 1.950 |
| 10 | 1.929 | 1.933 | 21 | 1.953 | 1.965 |
| 11 | 1.937 | 1.943 | 22 | 1.946 | 1.947 |
| 12 | 1.918 | 1.924 | 24 | 1.943 | 1.950 |
| 13 | 1.935 | 1.939 | 25 | 1.936 | 1.943 |
| 14 | 1.910 | 1.917 | 26 | 1.943 | 1.950 |
| 15 | 1.926 | 1.929 | | | |

## SOLAR CONSTANT AND SUN SPOTS.

By A. ÅNGSTRÖM.

[Abstract reprinted from *Meteorologische Zeitschrift*, Aug., 1921, pp. 250-251.]

In the *Geografiska Annaler* [1] there is given an instructive coordination of the Abbot solar-constant values and the relative sun-spot numbers of Wolfer for the years 1905 to 1917. The values are the annual means.

| Year | Sun spot number $N$. | Solar constant $S$. | |
|---|---|---|---|
| | | Observed. | Calculated. |
| 1905 | 63 | 1.956 | 1.946 |
| 1906 | 58 | 1.942 | 1.945 |
| 1907 | | | |
| 1908 | 55 | 1.936 | 1.944 |
| 1909 | 46 | 1.918 | 1.940 |
| 1910 | 21 | 1.921 | 1.928 |
| 1911 | 3 | 1.921 | 1.922 |
| 1912 | | | |
| 1913 | 1 | 1.904 | 1.900 |
| 1914 | 9 | 1.956 | 1.919 |
| 1915 | 62 | 1.952 | 1.946 |
| 1916 | 50 | 1.946 | 1.942 |
| 1917 | 113 | 1.960 | 1.961 |

A high sun-spot number implies a high solar constant. The coefficient of correlation between $S$ and $N$ Ångström calculates to be $0.64 \pm 0.12$. A better agreement is found, however, between the solar constant and the square root of the spot number. Here the correlation coefficient is $0.754 \pm 0.09$. This relation is important, for it indicates that the square root of the sun-spot numbers is a better index of solar activity than the numbers themselves. For the relation between $S$ and $N$, Ångström finds the following formula: $S = 1.93 + 0.0055\sqrt{N}$ gram-calories; with this formula the column in the table headed "Calculated" is determined.

Ångström adds with foresight that by no means does the agreement in a sun-spot period persist so that one may speak with assurance, although the validity of the relation appears very probable.—*F. M. E.*

[1] 1920, 2: 162.

551.524 (782) ~~(784)~~

## SUPPLEMENTAL NOTE ON FREE-AIR TEMPERATURE AT DREXEL AND ELLENDALE DURING THE WARM SUMMER OF 1921.

In this REVIEW for July, 1921, page 387, reference was made to the high free-air temperatures as obtained by kites at the two stations above named during the abnormally warm winter of 1920–21. The observations for August, 1921, are now available. These, like those for the preceding month, show that the temperature, from the surface up to 1,000 meters above sea-level, was slightly below the average and that above this level the temperature was higher than the average. Thus it appears that the free-air temperature above the stations named has been above the average for three successive months, particularly in June.

In previous studies it has been shown that abnormalities in the surface distribution of temperature are reflected in the free air up to a considerable height, probably to 5 km., although the kite observations at that level are not numerous. The natural explanation of the high temperature seems to be analogous to the one governing the surface distribution—viz, insolation plus transportation of heated air from lower latitudes. Through the courtesy of the Aerological Division, I am able to present the table below, which shows the average resultant free-air winds at successive levels in steps of 500 meters up to the greatest height reached by the kites at the stations above named for June, and also for comparison therewith the resultant winds for June, 1921.

TABLE 1.—*Resultant winds (average and for June, 1921) in free air at Drexel, Nebr., and Ellendale, N. Dak.*

[The Drexel average is for five years; Ellendale is for three years.]

| | Altitude (meters above sea level). | | | | | |
|---|---|---|---|---|---|---|
| | 396 | 444 | 1,000 | 1,500 | 2,000 | 2,500 |
| Drexel: | | | | | | |
| 5-year average | S. 19° W. | ............ | S. 46° W. | S. 69° W. | S. 72° W. | S. 83° W. |
| June, 1921 | S. 7° E. | ............ | S. 11° W. | S. 16° W. | S. 20° W. | S. 10° W. |
| Ellendale: | | | | | | |
| 3-year average | ............ | N. 73° E. | S. 31° E. | S. 54° W. | S. 66° W. | S. 82° W. |
| June, 1921 | ............ | S. 25° E. | S. 10° W. | S. 26° W. | S. 36° W. | S. 40° W. |

| | Altitude (meters above sea level). | | | | |
|---|---|---|---|---|---|
| | 3,000 | 3,500 | 4,000 | 4,500 | 5,000 |
| Drexel: | | | | | |
| 5-year average | S. 89° W. | N. 89° W. | N. 78° W. | N. 67° W. | N. 51° W. |
| June, 1921 | S. 26° W. | S. 14° W. | S. 30° E. | S. 40° E. | N. 68° E. |
| Ellendale: | | | | | |
| 3-year average | N. 89° W. | N. 87° W. | N. 75° W. | N. 70° W. | ............ |
| June, 1921 | S. 41° W. | S. 18° W. | S. 23° W. | N. 45° W. | ............ |

The striking feature of the table is the fact that southerly winds prevailed up to a level about 1,000 meters higher than the average, and as a consequence the lower limit of the northerly winds, which on the average prevail down to the 3,500-meter level, was elevated somewhat. May it not be assumed that the effect of the unusual warmth in June was cumulative during July and August, and that there is a considerable lag in the temperature of the free air as compared with the surface air?—*A. J. Henry.*